# Position Description

## FACTOR I. – RESEARCH ASSIGNMENT

### A. Research Organization

This position is in the Sound Branch of the Airplane Competency. The Sound Branch performs acoustics research to understand and control noise and its effects on aircraft, rotorcraft, and spacecraft structures, passengers, crew, and impacted community residents.

### B. Personal Research

The incumbent conducts research to develop adaptive structures technology for a range of acoustic, vibration, and aerodynamic applications. In particular, shape memory alloys (SMA) offer great potential for such applications but require significant advances to be made on several fronts, including modeling and design, fabrication and testing, and application-specific concept development and implementation. Success in these endeavors will likely lead to additional, fruitful areas of study and unexpected applications. The funding for this effort is primarily from the Morphing Program, with additional support from the Quiet Aircraft Technology program. The incumbent plans, leads, and conducts applied research to advance the understanding and application of shape memory alloys for aerospace applications. To accomplish this assignment effectively, the incumbent has broad experience that enables the modeling, design, fabrication and testing of adaptive structures. This complex area of research requires knowledge and experience, which the incumbent has, of static and dynamic structural analysis and testing, materials modeling and characterization, and fabrication techniques applicable to composite structures.

The central activity is the development and validation of models suitable for SMA and SMA hybrid composite structures. The incumbent applies this knowledge to projects aimed at particular applications and requires the incumbent to formulate and execute a research and design approach. This frequently involves the participation of other organizations both within and outside LaRC. Example projects include the modeling, design, fabrication, and testing of hybrid composite structures that adaptively stiffen in response to changing thermal conditions, thus yielding vibration suppression. Other projects are directed at changes in structural shape, with application to aerodynamic surfaces and noise control. If successful, such projects will provide one of the technology foundations necessary for morphing structures, thus enabling a broad range of new applications both in aerospace and elsewhere.

### C. Team Leadership

The incumbent plans, coordinates and integrates a range of technologies and the associated researchers to develop and test adaptive structures. A typical project has a multi-disciplinary team consisting of researchers in metallic materials, test engineers for structural testing, and composite fabrication specialists. The incumbent's primary role as team leader is to provide the technical leadership necessary to ensure that the component technologies result in a coherent and viable research approach. The incumbent leads the model development and validation efforts and provides the technical direction for the material characterization and fabrication work. This includes definition of performance goals, identification and assessment of limitations of component technologies, and overcoming problems associated with system integration.

As team leader, the incumbent is responsible for developing, on an annual basis, work packages for incorporation into the Center's Morphing program. He also is responsible for evaluating progress, and reporting progress, as necessary, to the Program Manager.

**D. Related Functions**

N/A

**E. Administrative Responsibilities**

The incumbent is expected to perform all administrative tasks associated with work package performance, including monitoring of grants, contracts, and SBIR awards. In addition, he forges inter-disciplinary cooperation through the formation of inter-competency teams, develops and advocates work packages, and interacts with industry to foster technology transfer.

**FACTOR II – SUPERVISION RECEIVED**

The incumbent reports to the Head of the Sound Branch who provides broad administrative supervision.

**A. Supervisory Relationship**

Within the broad framework of the development of adaptive structures for application to aerospace, the incumbent is expected to identify and explore the most promising avenues of research. The researcher has total responsibility for generating project plans, enlisting the support of contributing organizations, and directing the research plan through to completion. The incumbent interprets research results and disseminates them to interested parties both within and outside LaRC.

**B. Required Approvals**

Within staffing and budget constraints imposed by the Program Manager and Supervisor, the incumbent has the freedom to formulate and execute the research plan. Technical supervision is minimal, and interactions with the supervisor reflect a reliance on the incumbent's judgment and recommendations. The incumbent is solely responsible for the technical direction of several research teams.

### C. Delegated Authority

Within the incumbent's broad area of expertise, the researcher represents LaRC in technical matters and interactions with organizations both within and outside the Agency. Many of the research projects require the participation of other branches at the Center and may also involve the enlistment of support from outside organizations such as material suppliers, software developers, and end users such as aircraft companies. The incumbent negotiates such cooperation. Furthermore, the incumbent represents and describes research plans and findings with outside technical organizations. He disseminates research plans and findings directly to outside technical organizations. His recommendations are sometimes the basis for Center project level action. For example, his recommendations to the Morphing project manager resulted in revised Level 2 milestones and additional resources being allocated to the incumbent's team to accomplish those milestones.

## FACTOR III – GUIDELINES AND ORIGINALITY

### A. Existing Knowledge

In the area of adaptive structures there is a paucity of guidance available in the literature. Most efforts performed to date have been "cut and try"; there has been no systematic effort to develop and validate the appropriate design and analysis tools. The challenge is to fully understand the underlying physics and to then to develop useful engineering systems. For example, much information is available on the fundamental metallurgical characteristics of shape memory alloys, however it is insufficient for engineering analysis. Also, information regarding integration of SMAs into applications is sparse and ad hoc. The use of SMA's in a structural system thus requires significant advances in modeling capabilities, fabrication technology, and engineering design.

### B. Originality Required

Because of the lack of available guidance, a high degree of ingenuity is required, which the incumbent applies to this position, to enable the development of useful adaptive structures. This nascent technology area requires a high degree of creativity in developing methods and extending existing theories to model these unique structural systems. Unique fabrication techniques are required, as are complex test techniques to quantify the performance of such structures for concept and model validation. There is very little guidance available in any of these areas and the complexity of the material and structural systems demands a creative, coordinated effort in all areas to make research progress.

### C. Demonstrated Originality

The researcher developed a new constitutive theory for SMA materials, and carried the theory through to produce a thermomechanical analysis for studying the static and dynamic performance of plate-type structures. The researcher developed a parallel research program to characterize these material systems and to fabricate subcomponent-scale SMA hybrid composite structures for concept demonstration and analysis validation. The model and thermomechanical analysis were validated using unique test techniques that allowed systematic assessment of the salient features of the analysis. This new modeling capability will enable structural analysts to design complex structures with advanced actuation schemes involving SMA, which has potential to lead to revolutionary aerospace concepts.

## FACTOR IV – QUALIFICATIONS AND SCIENTIFIC CONTRIBUTIONS

The incumbent has an advanced degree in an appropriate engineering field and approximately 10 years experience in conducting research in adaptive structures and structural acoustics.

The incumbent provides technical leadership and consultation in the research field of adaptive structures for aerospace applications, an area of considerable importance to NASA. The incumbent leads a productive, multidisciplinary team of researchers from three Competencies by providing novel ideas and technical guidance. The incumbent has recognition among peers in government and industry and be known as a primary source of capability in his field. The incumbent has extensive experience with materials modeling, materials characterization, composite structural fabrication, advanced modeling of static and dynamic structural response involving material and geometric nonlinearities, static and dynamic structural test development, and advanced structural actuation concept development. Contributions to the field of adaptive structures from the incumbent are recognized through technical publications and professional society presentations, requests for technical assistance, and invitations to participate in collaborative, multi-disciplinary, research endeavors.

### Employee Accomplishment Record

1. **Name:** Ted D. Baer

2. **Education:**
   Ph.D., Engineering Mechanics, Georgia Institute, 2000
   M.S., Engineering Mechanics, Virginia University, 1991
   B.S., Mechanical Engineering, (Cum Laude) North Carolina University, 1987

3. **Relevant Professional Training Received:**
   - Engineering and Designing Smart Structures, 3-day short course, sponsored by VPI&SU, 1999.
   - Numerical Acoustics, 2-day short course, sponsored by Automated Analysis Corp., 2000.
   - Modal Analysis: Theory and Applications, 3-day short course, sponsored by B&K, 1989.
   - Hypersonic Vehicle Heat Transfer and Thermal Stress, 5-day short course, sponsored by Old Dominion University, 1987.

**4. - 6. Professional Experience, Accomplishments, and Leadership:**

**Assignment 1, *Shape Memory Alloys*** (1997-Present) 100% time spent (80% research, 20% admin duties); Code R Morphing Program; Supervisor: Dr. Patrick Kenner, Head of the Sound Branch (SB)

*a. Modeling and Validation for SMAs and SMA Hybrid Composite Structures* (25% time):
Dr. Baer leads an effort to develop constitutive models for SMA actuators, alone or embedded within a composite structure, to enable prediction of the thermomechanical performance of advanced structural concepts. His recent research focuses on development of technology for novel aerospace structural concepts involving shape memory alloys (SMAs) for vibration, noise transmission, and structural shape control applications. He maintains a lead role in all aspects of this work, which has been primarily funded by the Aircraft Morphing Project with secondary funding from the High-Speed Research and Quiet Aircraft Technology Programs. This work includes numerical modeling, materials characterization and processing, structural fabrication, adaptive structural concepts development, and experimental testing components. Applications of particular current and ongoing interest include adaptive stiffening for vibration/noise control and sonic fatigue abatement and structural shape control for adaptive airfoil bumps for shock alleviation, seamless airfoil control surfaces, and jet noise reduction.

There is a lack of accurate and practical constitutive models that will allow broad-scale thermomechanical analysis. All known structural concepts involving SMAs have been developed based upon "build and try" methodology. Dr. Baer developed a new constitutive model for SMA materials, alone or embedded within a composite structure, by definition of an effective (nonlinear) coefficient of thermal expansion (termed ECTE model). The ECTE model captures the thermoelastic nonlinearity of SMA materials but is macromechanical in nature such that it depends only upon measurement of fundamental engineering properties to predict performance. The model was developed in a form that can be implemented in any general-purpose analysis environment having appropriate nonlinear analysis capabilities. The ECTE model was first used to develop an in-house finite element structural analysis capability to study the thermomechanical performance of SMAs and SMAHC beam and plate-type structures. See the associated invention disclosure (8.2), positive technology transfer (PTT # 1396), and references 1, 4 and 5. The SMA modeling effort involves a Professor and Post-Doctoral Research Associate at Northwestern University (NWU) by cooperative agreement and two developers at MSC.Software Corporation by contract. Dr. Baer leads and coordinates this effort by guiding the research performed at NWU, integrating results from that work with developments at NASA LaRC. (Contacts: Davis, Yue, Right, Light, Lesser, Kincaid).

Coupon and subcomponent scale SMAHC structures have been fabricated using the SMA actuator processing and SMAHC fabrication methods described in *4b*. Dr. Baer developed complex experimental apparatus and methods to test these structures under application-representative conditions for concept demonstration and numerical analysis validation, as seen in references 2, 5, 9, and 11. The constitutive model and the associated structural analysis approach were validated through comparison with experimental data. These experimental results demonstrated the ability of SMA actuators to suppress thermal buckling under substantial thermal loads and to drastically reduce the peak and RMS responses of such structures under broadband random excitation (84% RMS reduction). This constituted the first known demonstration of thermal buckling control and the first known quantitative validation of a thermomechanical model for SMAHC structures. (Contacts: Davis, Yue, Right, Light, Lesser, Kincaid)

The ECTE constitutive model and associated thermomechanical analysis and feasibility studies conducted using the in-house code led to a cost-sharing contractual agreement with MSC.Software to implement the model in MSC.NASTRAN, which is the primary analysis tool of aerospace structural analysts. Dr. Baer led an effort with MSC.Software to implement the ECTE model in MSC.NASTRAN and is currently working with MSC.Software representatives to validate the implementation. This development will enable broad distribution of an analysis capability for structural concepts involving SMA. Such concepts are currently of significant interest in Government, academia, and industry. See the associated positive technology transfer item (PTT # 1396). (Contacts: Davis, Right, Rogers)

*b. Characterization and Processing of SMA Materials* (25% time*)*:
Dr. Baer leads a team at LaRC to develop materials characterization methods to better understand SMA materials and to provide material property data for analysis and application integration. He also leads a concurrent effort to develop processing methods for SMA materials to produce reliable, consistent actuators and to automate the production of SMA actuators. The SMA materials characterization and processing work is a collaborative effort involving two engineers in the Metal Structures Branch, four contractors (Lockheed Martin) assigned to the Light Alloy Laboratory, one engineer and one technician in the Materials Application and Integration Section of another Competency and one contractor (Lockheed Martin) assigned to the Aero Branch. Dr. Baer coordinates and leads this effort by developing several specialized characterization and processing methods, developing specialized hardware to facilitate performing these tasks, developing large-scale characterization and processing concepts for detailed implementation by the group members, and allocating resources as well as tasks between the research and engineering components of the group to separate the more well defined production work from the more open-ended scientific work.

The microstructural (crystalline), transformation, and thermomechanical characteristics of SMA materials are very complex. There is a significant body of literature on this topic, but much is yet to be learned about these materials. Dr. Baer leads an effort to develop a SMA materials characterization capability at LaRC to better understand these materials and provide material property data for numerical model development and application integration. The effort spans three competencies and is the only known SMA characterization capability within NASA. The work within this area includes differential scanning calorimetry, x-ray diffraction, tensile testing, and resistivity testing, all of which have undergone significant specializations and require detailed interpretation to form the comprehensive characterization capability at LaRC. Important material characteristics, e.g., large variations in mechanical modulus and unexpected tensile behavior, have been discovered in this work. These discoveries have significant implications for modeling these materials and for integration of SMA actuators into applications, see references 5, 8, and 10. Thermomechanical cycle dependency is another complexity of particular interest for applications. Dr. Baer developed an automated process to measure this cycle dependency and is in the process of extending that technology to automation of thermomechanical "training" of SMA actuators (see Section 10, Hardware Products). (Contacts: Davis, Yue, Right, Light, Lesser, Hammer, Kincaid)

Frequently, applications require a significant number of SMA actuators. Each actuator must be processed within close tolerances to produce desirable performance characteristics, which may include thermomechanical training, so processing the required number of actuators can be very time/work intensive. Dr. Baer has developed methods for mass-producing processed SMA actuators. One particularly versatile concept led to the invention disclosure described in 8a and is in the process of being implemented. This automated SMA actuator processing concept has potential to reduce actuator-processing time by a factor of 10 or more and can produce an arbitrary number of actuators of arbitrary length. This concept is related to the SMAHC fabrication technology described subsequently. See the associated invention disclosure (8.1) for details. (Contacts: Davis, Right, Hammer)

*c. Fabrication and Testing of SMA Hybrid Composite (SMAHC) Structures* (25% time): Dr. Baer leads a team at LaRC in the development of fabrication methods for embedding SMA actuators in laminated composite structures. Dr. Baer developed complex test apparatus and test techniques to demonstrate the static and dynamic thermomechanical performance of these structures. The SMAHC fabrication work is a collaborative effort involving one engineer in the Mechanics and Durability Branch of another Competency and one engineer and one technician in the Materials and Processing Branch (MPB) in a second Competency. Dr. Baer leads this effort by conceiving of the fabrication method, designing candidate test structures, overseeing specialized fabrication hardware development, and participating in the fabrication process as well as in the development of refinements.

In many applications it is desirable to embed SMA actuators in a composite material. Various researchers have attempted implementation of this concept with very limited success because of the complex nature of the process and sensitivity of the SMA actuators to interface flaws and stress risers at mechanical constraints. Furthermore, all known processes are strictly limited to hand layup-type procedures. Dr. Baer led an effort to develop a composite layup process that addresses all of these issues. This process not only produces reliable, consistent consolidated parts, but also is extensible to automation and is the only commercially viable process known for embedding SMA actuators in laminated composite structures. Development of the process led to the invention disclosure (8.3). Additional information can be found in references 1, 5, 9, and

10. Dr. Baer has recently been formulating plans with personnel in the Materials and Processing Branch and the Materials Application and Integration Section to incorporate the automated SMA actuator-processing concept, described above, with this fabrication process in a completely automated SMA hybrid composite consolidation process with electron-beam curing. The work at NASA LaRC to automate SMA actuator processing and fabrication of composite structures with embedded SMA actuators is the only known effort of this type. (Contacts: Davis, Yue, Right, Light, Lesser, Hammer, Kincaid)

*d. Development of Structural Actuation Concepts (*25% time): Dr. Baer's extensive work (including modeling, characterization, and fabrication) with a variety of smart materials structural actuation concepts, particularly those involving SMA materials, has stimulated collaborative work with various groups on projects including adaptive wing concepts for performance enhancement and flight control, adaptive airfoil bumps for shock and flight control, adaptive jet exhaust chevrons for noise control, adaptive synthetic spoilers for flight control, and adaptive UAV wing concepts for gust load alleviation.

**Assignment 2**, ***Sonic Fatigue Group Activities***, (1988-1999); 100% time spent (100% research); Code R High Speed Research and Advanced Subsonic Transportation Programs; Supervisor: Dr. Patrick Kenner, Head of the Sound Branch (SB)

The researcher participated in a team effort within the Sonic Fatigue Group (SFG) of the Sound Branch (SB) to develop numerical analysis methods, advanced structural concepts, and experimental test methods to enable efficient and durable structural designs for harsh thermal-acoustic environments. Work performed by the researcher within the SFG consisted of 1) modal and sonic fatigue testing of advanced structural concepts, 2) development and validation of a numerical analysis method for prediction of geometrically nonlinear random vibration of flexible aerospace structures, 3) conducting experimental studies of the thermal performance of a unique experimental test facility, and 4) development of numerical analysis capabilities for predicting the radiant thermal load produced by quartz heating systems and the thermal response of candidate test structures to the imposed radiant thermal load. The researcher also participated in a major upgrade project on a uniquely capable experimental test facility. Initial interest in shape memory alloys was developed in the SB within the context of sonic fatigue because of the potential for broadband vibration control by SMA actuation. The researcher worked collaboratively with academia and industry on development of fabrication and analysis methods for hybrid composite structures with embedded SMA actuators. An in-house numerical analysis capability for such SMAHC structures was developed and application feasibility studies were conducted. This work formed some of the pioneering studies of SMA materials for dynamic response applications, which led to the focused work described in 4a. Work within the context of sonic fatigue was supported primarily by the High Speed Research (HSR) and the National Aerospace Plane (NASP) Programs and was led by Dr. Stephen Right. The researcher also worked within the Interior Noise Reduction Group of the SB to develop characterization and modeling capabilities for piezoelectric (primarily PZT) actuators. Other work in this area included participation in planning and performance of a qualification test for a piezo-shunt system for vibration control of aircraft panels. This work was performed as part of the memorandum of agreement (SAA #452, see section 10) and resulted in the first known demonstration of multi-modal control by a piezoelectric shunt system on a practical structure and under realistic load conditions. The interior noise work was supported by the Advanced Subsonic Transportation Program and was led by Dr. Richard Jackson.

High performance aerospace vehicles present unique problems for structural design because of the need for weight-efficient structures and the presence of intense thermal, acoustic, and mechanical loads. This situation has mandated development of analysis and testing technology to better understand and predict the response of such structures, which may include complex behavior such as material and geometric nonlinearity. The Sonic Fatigue Group developed an analysis method to predict geometrically nonlinear random response of such structures and implemented the analysis in the general-purpose finite element analysis environment MSC.NASTRAN for broad-scale use by aerospace analysts. The researcher participated in numerical analysis development, monitored contract tasks to update and enhance the capabilities of the analysis, assisted in implementation of the analysis in MSC.NASTRAN, and played an integral role in research aimed at establishing the range of validity of the analysis method by comparison with experimental measurement. The researcher developed and conducted a series of geometrically nonlinear random vibration tests to generate benchmark experimental data for analysis validation. Experimental data from this testing provided valuable insight into the breadth of the analysis applicability and opened a new area of research by exposing analysis limitations. The analysis capability has been very valuable to industrial counterparts as evidenced by PTT #s 989, 45, 44, and 43, for which the researcher was a contributor (also see reference 15). The researcher also participated in performing characterization tests of a unique thermal acoustic test facility following a major facility upgrade and resulted in a Superior Accomplishment Award (see 9c, and reference 17). The researcher conducted tests to characterize the radiant thermal load developed by the specimen heating system in this test facility and developed an in-house thermal analysis capability, prior to the test facility upgrade, to predict the radiant heat transfer from such heating systems. This analysis capability enabled design of heating system upgrades, design of other system upgrades, development of specimen-specific test plans, and prediction of the thermal response of candidate test structures. The radiant thermal analysis is in a modular form that is amenable to adaptation to arbitrary system configurations, which enabled the PTT # 1395. (Contacts: Right, Yue)

The researcher conducted collaborative research with Old Dominion University and what was then McDonnell Douglas Corporation (MDC) to develop adaptive structures technology for thermal-acoustic fatigue applications. He developed constitutive models and structural analysis methods for predicting the static and dynamic responses of composite structures with embedded SMA actuators. Little precedent existed for guidance, particularly for practical analysis tools. He conducted feasibility studies to determine the potential effectiveness of SMA actuators for a variety of applications, which formed some of the pioneering work in this area. Successes from these feasibility studies served as impetus for further developments, described above in *4a* and *b*, and led to inclusion of a more formal relationship with MDC/Boeing on these topics in a

Memorandum of Agreement (MOA SAA #452, see section 10). Also see references 12, 16, 19, and 20. (Contact: Yue)

**7. Professional Scientific/Engineering/Technical Service:**

a. *Memberships in Professional Societies*

- Senior Member, American Institute for Aeronautics and Astronautics (1990-Present)
- Member, American Society of Mechanical Engineers (1986-Present)

b. *Rendering Scientific Judgment*

- Occasional Reviewer for Journals: AIAA Journal of Aircraft, Journal of Sound and Vibration, ASME Journal of Vibration and Acoustics, AIAA Journal, and Finite Elements in Analysis and Design
- Reviewer for Triennial Conference, International Conference on Recent Advances in Structural Dynamics, Institute of Sound and Vibration Research, University of Southampton, England.
- Reviewer of SBIR proposals for multiple organizations; Sound Branch (APC), and for other Competencies (Structural Dynamics Branch, Materials and Processing Branch)

c. *Special Assignments or Other Outreach Activities*

- Co-instructor for an AIAA short course, Design and Analysis of Surface Panels for High Speed Vehicles, to be offered in conjunction with the 44$^{th}$ SDM Conference, April 2003, Norfolk, VA.
- Member of the Technical Program Committee for SPIE's 7th International Symposium on Smart Structures and Materials, Newport Beach, CA, 2000.
- Technical session chairman for SPIE's 7th International Symposium on Smart Structures and Materials, Newport Beach, CA, 2000.
- Member of the local organizing committee for the Acoustical Society of America semi-annual meeting held in Norfolk, VA, 1998.
- Technical session chairman for the 6$^{th}$ International Conference on Recent Advances in Structural Dynamics, ISVR, University of Southampton, England, 1997.
- Technical session chairman for the 36$^{th}$ AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, New Orleans, LA, 1995.
- COTR on STTR Contract NAS1-00002 with Cornerstone Research Group, Laser Processing of Thin-Film Mirrors Using Shape Memory Polymers, 1999.
- Grant monitor for Old Dominion University on modeling of piezo-structures for vibration and structural acoustic control.. Grant Nos. NAG1-1684 and NAG1-2141, 1995-2000.

**8. Inventions, Patents Held:**
**Invention Disclosures**

1. LAR-16329-1, "Automation of the Prestrain (Elongation) Operation of Shape Memory Alloy Actuators," 2001.

2. LAR-16274-1, "Nonlinear Thermoelastic Model for Shape Memory Alloys (SMAs) and SMA Hybrid Composites," 2001.

3. LAR-16273-1, "Fabrication Method for Composite Structures with Embedded Shape Memory Alloy Actuators," 2001.

**9. Honors, Awards, Recognition, Elected Memberships:**

1. Received a Quality Step Increase, 2001.

2. Received Certificate of Appreciation from Advanced Subsonic Technology Program for contributions to "successful demonstration of advanced noise reduction technologies for aircraft applications," 2001.

3. Received Certificate of Appreciation from High Speed Research Program for "significant contributions toward the achievement of NASA High-Speed Research Program goals," 1999.

4. First runner-up in AIAA Hampton Roads Section "Young Professionals Paper Competition" for journal publication entitled "A New Thermoelastic Model for Analysis of Shape Memory Alloy Hybrid Composites," 2000 (see reference 4).

5. Received Superior Accomplishment Award for "design, development, and implementation of a uniquely capable sonic fatigue test facility," 1997.

6. Received Performance Award Certificates for "Sustained Efforts in the Development of Smart Structures Technology," 1996, 1999, 2000, 2001.

7. Received Certificate of Outstanding Performance, 1996.

**10. Work Product List:**
**Books**

1. Baer, Ted L.: Shape Memory Alloy Hybrid Composites for Adaptive Vibration and Noise Control, under preparation for Springer-Verlag.

**Formal Refereed Publications**

2. Baer, Ted L.: Experimental Demonstration of Structural Thermoelastic and Dynamic Response Control by Shape Memory Alloy Actuators, submitted to the Journal of Intelligent Material Systems and Structures.

3. Baer, Ted L.: SMA Hybrid Composites for Dynamic Response Abatement Applications, submitted to the Journal of Intelligent Material Systems and Structures.

4. Baer, Ted L.: A New Thermoelastic Model for Analysis of Shape Memory Alloy Hybrid Composites, Journal of Intelligent Material System and Structures 11(5) 382-394, May 2000.

5. Baer, T. L.: Thermomechanical Response of Shape Memory Alloy Hybrid Composites. Virginia Polytechnic Institute and State University, Fall 2000. (Ph.D. Dissertation).

6. Baer, Ted L. and Ash, Robert L.: Numerical and Experimental Analyses of the Radiant Heat Flux Produced by Quartz Heating Systems. NASA TP 3387, March 1994.

7. Baer, T. L.: Simulation and Measurement of the Radiant Field Produced by Quartz Heating Systems. Old Dominion University, Fall 1991. (M.S. Thesis)

**Referenceable Oral Presentations**

8. Case, Cynthia L.; Baer, Ted L.; Ranger, Karen M.; and Shinny, Raves N.: Effects of Thermomechanical History on the Tensile Behavior of Nitinol Ribbon. SPIE's 9th International Symposium on Smart Structures and Materials, 17-21 March 2002, San Diego, CA, SPIE 4699-45.

9. Baer, Ted L.: Structural Acoustic Response of a Shape Memory Alloy Hybrid Composite Panel (Lessons Learned). SPIE's 9th International Symposium on Smart Structures and Materials, 17-21 March 2002, San Diego, CA, SPIE 4701-60.

10. Baer, Ted L.; Case, Cynthia L.; Wheat, Roberto J.: Fabrication and Characterization of SMA Hybrid Composites. SPIE's 8th Annual International Symposium on Smart Structures and Materials, 4-8 March 2001, Newport Beach, CA, SPIE 4333-60.

11. Baer, Ted L.: Experimental Validation of a Thermoelastic Model for SMA Hybrid Composites. SPIE's 8th Annual International Symposium on Smart Structures and Materials, 4-8 March 2001, Newport Beach, CA, SPIE 4326-24.

12. Baer, Ted L.: SMA Hybrid Composites for Dynamic Response Abatement Applications. Seventh International Conference on Recent Advances in Structural Dynamics, Southampton, England, 24-27 July 2000, pp. 453-465.

13. Wu, Shu-Yau; Baer, Ted L; and Right, Stephen A.: Piezoelectric Shunt Vibration Damping of an F-15 Panel under High Acoustic Excitation. SPIE's 7th

International Symposium on Smart Structures and Materials, Damping and Isolation (ss06), Newport Beach, CA, 5-9 March 2000, SPIE 3989-27.

14. Baer, Ted L: Dynamic Response Tuning of Composite Beams by Embedded Shape Memory Alloy Actuators. SPIE's 7th International Symposium on Smart Structures and Materials, Industrial and Commercial Applications of Smart Structures Technologies (ss08), Newport Beach, CA, 5-9 March 2000, SPIE 3991-47.

15. Moravian, Alexander; Baer, Ted L.; Robinson, Jay H.: A New Stochastic Equivalent Linearization Implementation for Prediction of Geometrically Nonlinear Vibrations. 40th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, St. Louis, MO, 12-15 April 1999, AIAA 99-1376.

16. Yue, Chub; Hung, Shire W.; and Baer, Ted L.: Control of Sonic Fatigue for High Speed Flight Vehicles Using Shape Memory Alloys. SPIE's 5th International Symposium on Smart Structures and Materials, San Diego, CA, 1-5 March 1998, SPIE Vol. 3326, pp. 498-508.

17. Right, Stephen A.; and Baer, Ted L.: Enhanced Capabilities of the NASA Langley Thermal Acoustic Fatigue Apparatus. Sixth International Conference on Recent Advances in Structural Dynamics, Southampton, England, 14-17 July 1997, pp. 919-933.

18. Baer, Ted L. and Right, Stephen A.: Prediction and Measurement of the Vibration and Acoustic Radiation of Panels Subjected to Acoustic Loading. 1995 International Conference on Noise Control Engineering (INTER-NOISE 95), 10-12 July 1995, Newport Beach, CA.

19. Baer, Ted L.; Light, Amender P.; and Yue, Chub: A Spectral Analysis Approach for Acoustic Radiation From Composite Panels. Presented at the AIAA/ASME/ASCE/AHS/ASC 36th Structures, Structural Dynamics, and Materials (SDM) Conference, April 10-12, 1995, New Orleans, LA, AIAA-95-1303-CP, pp. 1262-1271.

20. Baer, T. L.; Hung, Z. W.; and Yue, C.: Finite Element Analysis of the Random Response Suppression of Composite Panels at Elevated Temperature Using Shape Memory Alloy Fibers. Presented at the AIAA/ASME/ASCE/AHS/ASC 35th Structures, Structural Dynamics, and Materials Conference, 18-21 April 1994, Hilton Head, SC, AIAA-94-1324-CP, pp. 136-146.

21. Baer, T. L.: Monte Carlo Simulation of the Radiant Field Produced by a Multiple Lamp Quartz Heating System. Presented at the AIAA/ASME/ASCE/AHS/ASC 32nd Structures, Structural Dynamics, and Materials (SDM) Conference, 8-10 April 1991, Baltimore, MD, AIAA-91-1150-CP, pp. 1393-1401.

22. Baer, T. L.; and Ash, R. L.: Analysis of the Thermal Environment and Thermal Response Associated with Thermal-Acoustic Testing. Presented at the AIAA/ASME/ASCE/AHS/ASC 31st Structures, Structural Dynamics, and Materials (SDM) Conference, 2-4 April 1990, Long Beach, CA, AIAA-90-0975-CP.

**Others**

23. Baer, Ted L.: Shape Memory Alloy Research at Langley Research Center, 2nd NASA Advanced Materials Symposium, Invited Presentation (Abstract and Langley Edge Publication), Cleveland, Ohio, May 2002.

24. Baer, Ted L.: Structural Acoustic and Shape Memory Alloy Research at NASA LaRC, Old Dominion University Graduate Seminar, Invited Presentation, February 2002.

25. Baer, Ted L.: Thermomechanical Response of Shape Memory Alloy Hybrid Composites. NASA TM-2001-210656, January 2001.

26. Baer, T. L.: Shape Memory Alloy Hybrid Composite Modeling and Validation, NASA Interior Noise Workshop, Presentation Only, February 2000.

27. Baer, Ted L.: Environmentally Activated SMA Hybrid Composites. Presented at Fourth ARO Workshop on Smart Structures, Penn State, 16-18 August 1999.

28. Moravian, A.; Baer, T. L., Robinson, J. H.; and Right, S. A.: Sonic Fatigue Structural Response Code Development, HSR Airframe Structures Annual Review, Presentation Only, February 1999.

29. Baer, T. L.: SMA Hybrid Composites, NASA Interior Noise Workshop, Presentation Only, February 1998.

30. Baer, T. L.: Sonic Fatigue Structural Response Code Development, HSR Airframe Structures Annual Review, Presentation Only, February 1998.

31. Baer, T. L.: SMA Composites for Sonic Fatigue Reduction, HSR Airframe Structures Annual Review, Volume I, 1997.

32. Baer, Ted L.: Structural Acoustic Response of Shape Memory Alloy Hybrid Composite Panels, Proceedings of the 4th Annual Workshop: Advances in Smart Materials for Aerospace Applications, NASA CP-10185, pp. 219-222, March 1996.

33. Baer, T. L.; and Ash, R. L.: Prediction of the Thermal Environmental and Thermal Response of Simple Panels Exposed to Radiant Heat. NASA TM 101660, October 1989.

34. Locke, James; Sullivan, Brenda; Baer, Ted; and Kenner, Patrick: Investigation of the Acoustic Response and Stresses of a 121-Foot Steel Flarestack, Internal Report for 8-Foot HTT safety investigation, 1989.

**System Study Reports**
None

**Hardware Products**
Automated SMA Recovery Force Measurement System (see 5b for details).

**Software Products**
ECTE constitutive model for SMA materials implementation in MSC.NASTRAN (see 5a for details and PTT # 1396).

Numerical analysis code (in-house, Monte Carlo simulation) for prediction of thermal radiation from quartz heating systems (see 5c for details and PTT # 1395).

Numerical analysis code (in-house, finite element) for modeling SMA and SMAHC constitutive behavior as well as static and dynamic thermomechanical behavior of beam and plate-type structures with SMA actuators (see 5a for details).

**External Agreements**
PTT # 1396, "Thermoelastic Constitutive Model for SMAs and SMAHCs", 2001
PTT # 1395, "Simulation of Radiant Heat Flux Produced by Quartz Heating Systems", 2001
PTT # 989, "Nonlinear Random Response Prediction Code V70.0", 1998
PTT # 45, "Nonlinear Random Response Prediction Code V68.2a", 1997
PTT # 44, "Nonlinear Random Response Prediction Code V68.2", 1996
PTT # 43, "Nonlinear Random Response Prediction Code V67r2", 1996

Memorandum of Agreement (SAA #452), Smart Materials and Structures Studies, NASA Langley Research Center and McDonnell Douglas Corporation, 1999-2001